Optimal Design of Wind/PV/Diesel/Battery Power System for telecommunication application in a remote Algeria

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Abstract— **Algeria has embarked on an ambitious renewable energy program in order to increase total food production. It has a large number of remote small villages and islands that lack in the electricity, and probability of connecting them with the high voltage gridlines in the near future is very poor due to financial and technical constraints.**

This paper proposes the use of a PV, wind and diesel generator hybrid system with storage element in order to determine the Optimal configuration of renewable energy in ALGERIA. The principals' interests of this system are the independence production, and the supplying of electric energy in isolated localities.

Have at one's the energetic and economic models, and simulation tools, we effected an optimization study based on mixed productions. For this approach, the energetic resources of sites where are implanted telecommunications systems and their consumption are supposed known. Then the problem is the optimization of electric generators using these resources, enable to have an optimal type system for the powering of telecommunications equipments in rural site of Algeria.

Homer (hybrid optimization model for electric renewable) simulation software was used to determine the technical feasibility of the system and to perform the economical analysis of the system.

Keywords*— *renewable energy, homer, photovoltaic energy, diesel, wind energy, optimization.

I. INTRODUCTION

Algeria have got no access to grid based electricity services, the majority of which live in underdeveloped rural areas. In order to realize sustainable human development.

Communication technology is one of the fastest growing technologies during these days. The telecommunication companies are continuously challenged to provide uninterrupted services to rural and remote areas where there is no reliable electrical power supply available. Therefore, renewable energy systems are becoming increasingly popular in those industries to provide uninterruptible power to remote areas. Currently in most cases the telecommunication stations use diesel generators connected with backup batteries to provide power. Increasing demand of energy and negative impacts of fossil fuels on the environment has emphasized the need of harnessing energy from renewable sources.

In this paper, a stand-alone hybrid alternative energy system is proposed for remote Algeria. In this case wind and PV are considered as the main power sources for the system and diesel generator and a battery bank are also integrated as a backup power supply. The diesel generator is treated as a mechanism to provide long-term power storage and the battery is used as a backup for short-term power storage.

II. DATA INPUT

A. Electrical Load

The record indicates the approximate power consumption for telecommunication system is 78.6kwh/day with 7.8kw peak and the system runs on 48v dc bus. Telecommunication companies are committed to provide uninterruptable service and therefore these sites require continuous power throughout the year [4], [9]. Therefore, the hourly load is almost a constant, as the power consumption remains the same. Telecommunication

Load profile is shown in figure 1 which is produced by homer [1].

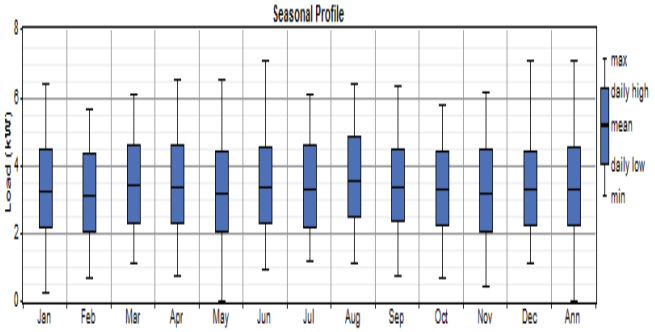

Fig.1 Diurnal variation of load during different months of the year

B. Geographical location of implementation site

Algeria's geographic location has several advantages for exten- sive use of most of the RES (solar and wind). Algeria, situated in the centre of North Africa. Algeria is divided into 48provinces and lies, in the north, on the coast of the Mediterranean Sea. The length of the coastline is 2400km. In the west Algeria share sits borders with Morocco, Mauritania and occidental Sahara, in the south west with Mali, in the east with Tunisia and Libya, and in the south east with

Niger (Fig. 1). The climate is transition al between maritime (north) and semi- arid to arid (middle and south). The Sahara (south of Algeria) covers a total area of 2,048,297km2, approximately 86% of the total area of the whole country. The geographic location of Algeria signifies that it is in a key position to play an important strategic role in the implementation of telecommunications systems powered by renewable energy. In our study we have to select station in the sahara of Algeria and where wind speed and solar irradiation are important and. We can select Adrar. [6], [7]. Geographical data for the selected site is shown in table 1.

TABLE I. GEOGRAPHICAL DATA FOR THE SELECTED STATIONS

Site	Longitude	Latitude	Altitude
Adrar	0°17'00"W	27°52'00"N	279m

III. RENEWABLE ENERGY RESOURCES

On account of its geographical location, algeria holds one of the highest solar potentials in the world which is estimated at 13.9 twh per year. The country receives annual sunshine exposure equivalent to 2,500 kwh/m^2. Daily solar energy potential varies from 4.66 kwh/m^2 in the north to 7.26 kwh/m^2 in the south. algeria has promising wind energy potential of about 35 twh/year. Our study suggests that the location at adrar telecommunication site has sufficient wind and solar energy for generating sufficient power for this application. Collecting weather data is one of the main tasks for this pre-feasibility study for a renewable energy system.

A. Solar energy resource

The average solar irradiation is 5.88 kWh/m²-d and sensitivity analysis is done with three different values. Clearness index and the average daily radiation for a year are shown in table 2 while figure 2 shows the solar radiation in a year produced by HOMER.

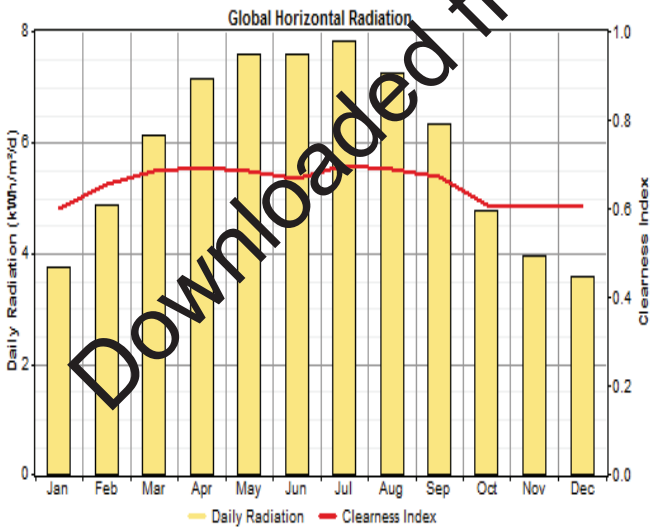

Fig.2 Monthly solar radiation

TABLE II. CLEARNESS INDEX AND AVERAGE DAILY RADIATION FOR A YEAR

Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.599	3.740
February	0.655	4.870
March	0.685	6.140
April	0.693	7.140
May	0.683	7.580
June	0.669	7.500
July	0.699	7.820
August	0.688	7.260
September	0.673	6.320
October	0.607	4.770
November	0.606	3.936
December	0.607	3.558

B. Wind energy resource

The second renewable source implemented in telecommunication system for adrar site is wind energy. wind data for this site are given by [10] where are used for our study. Figure 3 shows the average hourly wind speed for a year. The average wind speed is estimated 6.3m/s and for sensitivity analysis three values of wind speed are chosen. The monthly average wind speed is shown in table 3.

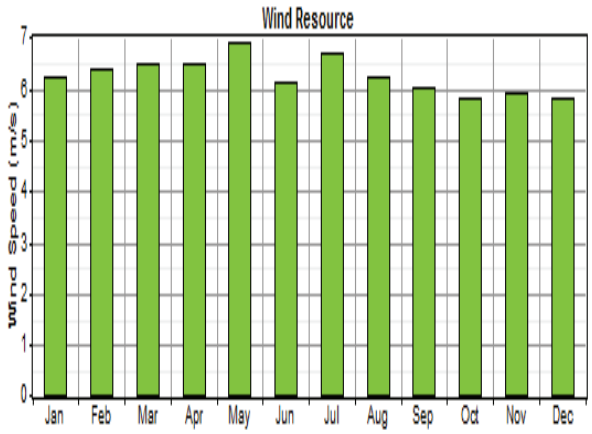

Fig.3 The average hourly wind speed for a year

TABLE III. MONTHLY AVERAGE WIND SPEED FOR A YEAR

Month	**Wind Speed (m/s)**
January	6.200
February	**6**.400
March	6.500
April	6.500
May	6.900
June	6.100
July	6.700
August	6.200
September	6.000
October	5.800
November	5.900
December	5.800

IV. RENEWABLE ENERGY SYSTEM

The proposed hybrid renewable energy system is shown in figure 4 which consists of the existing power system, wind turbine, and photovoltaic. The proposed system is going to reduce diesel fuel consumption and associated operation and maintenance cost. In this system the wind turbines and PV will be the primary power source and diesel generator will be using as a backup for long term storage system and batteries for short term storage system.

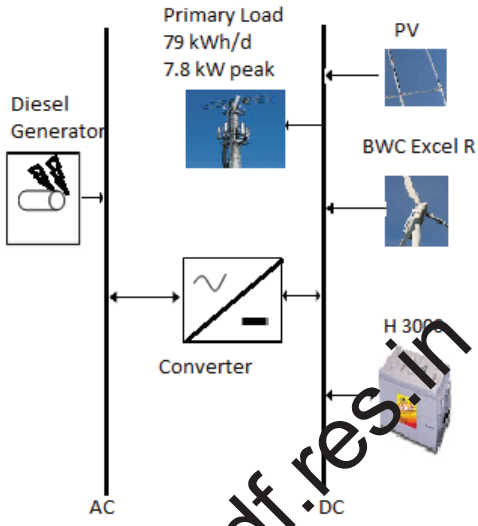

Fig.4 Proposed hybrid power system for adrar site

A. Solar panels

solar panels used in this system are STP280-24 each IVmodule panel provides 280W with 24V. Therefore, two PV modules are connected in series to meet the bus voltage which is 48V. A total of 5.6kW PV rated capacity is used in this system. Modules are connected in 10 strings each string has two modules with twenty modules in total. provides 280W with 24V. therefore, two PV modules are connected in series to meet the bus voltage which is 48V.

B. Wind turbine

Two BWC-Excel-R/48 are used in this system. Each one has rated capacity 7.5kW and provides 48V DC.

V. RESULTS AND DISCUSSION

TABLE IV. PRODUCTION OF HYBRID POWER GENERATOR

PRODUCTION	KWH/YEAR	%
PV ARRAY	10 260	32
WIND TURBINES	14735	46
DIESEL	6921	22
TOTAL	31915	100
CONSUMPTION DC LOAD	28835	100

The power system alimented radio telecommunication have two renewable sources and diesel generator, and it is the optimized system. the production of each system is shown in Tab4.

Photovoltaic production is 32% with 10260kWh/yr. Diesel generator production is 22% with 6921kWh/yr. Finally, wind turbine is expected to supply the rest of the load which is 46% with 14735kWh/yr.

Figure 5 shows the monthly average electric production of the system.

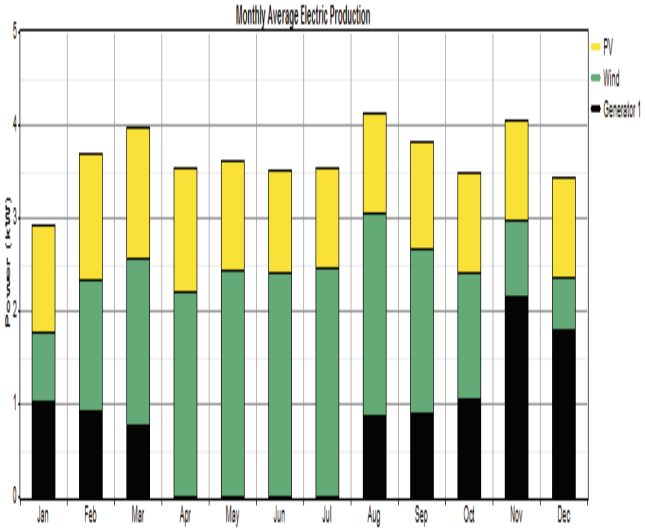

Fig.5 Monthly average electric production for renewable energy system

In Tab 5 we can see that the power system provide a considerable part from renewable energy with a fraction of 78.3%.this result confirm the feasibility of this energy system in remote Algeria.

TABLE V
values of optimized power system

Quantity	kWh/yr	Value %
Excess electricity	**0.00000973**	**0.000**
Unmet electric load	**0.00000262**	**0.000**
Capacity shortage	**237**	**0.8230**
Renewable fraction		**78.3**

Both systems are simulated in HOMER software, and the optimal results were obtained for each case. Figure 6 shows the optimization result for the non-renewable energy system. As shown in the figure the total Net Present Cost (NPC) is $823,072. Diesel generator burns 12,672L of fuel per year and annual generator run time is 1,536 hours. In twenty years the diesel generator will burn 25,3440L of fuel. For this site the diesel fuel can be transported only by a helicopter. Therefore the total cost of diesel fuel at $5 per liter, would be very high. The probability of fuel prices increase is also high. The total cost is calculated with constant price of fuel, which is $5 per liter. The total fuel cost during these 20 years will be $1,267,200 and the total cost for the whole system will be $2,090,272. Figure 7 shows the monthly average electric production of the system which is totally produced by diesel generator.

Fig.6 Optimized result for the renewable energy system

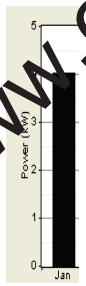

Fig.8 Monthly average electric production for non-renewable energy system

The renewable energy based system was also simulated in HOMER software with four sensitivity variables. These variables are wind speed, solar irradiation, load, and diesel price and each of these variables has three different values. Therefore, 81 sensitivity cases have been tested for the system. Figure 8 shows the optimized results for the proposed system. The total Net Present Cost (NPC) is $1,011,514. The system will consume only 335 liters of diesel fuel per year and annual generator run time is expected to be 145 hours. The lifetime of this system is 25 years, but 20 years life is used to make the comparison between two systems. In twenty years the diesel generator will burn 6,700L of fuel and it will cost $33,500. The total cost of the system will be around $1,045,014. Figure 9 shows the monthly average electric production of the system. Photovoltaic production is 14% with 6,403kWh/yr. Diesel generator production is 2% with 1,052kWh/yr. Finally, wind turbine is expected to supply the rest of the load which is 84% with 38,325kWh/yr.

The difference cost between two systems is $1,045,258 which is a very significant number for a small system. Diesel generator run times are reduced and diesel generator in the proposed system will produce only 2% of the total power production. Moreover, the reduction of yearly diesel fuel consumption from 12,672L to 335L has a large impact on the environment and it will reduce the helicopter trips to the site. Also, the diesel generator will require less maintenance and operation cost and longer period of service before a replacement.

VI. CONCLUSION

Renewable energy resources selected to supply a sample of telecommunication systems and the optimization of power generators using these resources helped us to have such an optimal system for supplying telecommunications equipment located in the middle rural Algeria.

These systems can be optimized subsequently controlled by a control circuit. So we can have depending on the availability of resources, one of the five combinations found in the optimal system type, and the telecommunications system will be powered permanently without any shortage and in all possible cases.

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